WATER FLUORIDATION: THE ENGINEERS' CONTRIBUTION

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Abstract

The benefits of fluoridation were formally endorsed in North America in 1951 and for nearly sixty years a diverse range of communities have been adjusting the fluoride content in water supplies to reduce dental decay. Australian fluoridation commenced in 1953 in Tasmania and expanded to the other states because of the enthusiastic efforts of engineers in partnership with the dental profession. The purpose of this paper is to highlight the early contribution of engineers in fluoridation research and to acknowledge the role of four Australian engineers, Mr F Grey (Tasmania), Mr H J N Hodgson (South Australia), Mr M A Simmonds (Queensland) and Dr M J Flynn (New South Wales). The history of fluoridation and the multidisciplinary approach to its implementation has relevance today as reuse of water and beneficial use of biosolids is subjected to community debate.

The Background to Water Fluoridation

In the early twentieth century tooth decay was in epidemic proportions causing not only tooth loss but, in this period before antibiotics and modern anaesthesia, generalised infections and death. The importance of a means of prevention could not be underestimated and one possibility emerged in North America. It was observed that people with 'mottled' teeth had fewer decayed teeth. This hypothesis was investigated and upheld by epidemiological studies that also confirmed a previously held suspicion that reduced dental decay was linked to the water supply. HV Churchill (chemical engineer) and AW Petrey (spectrographic analyst) made a pivotal contribution to this research in 1931 when they developed a water-borne fluoride assay technique (Churchill 1931).

In 1942, after further multidisciplinary research and epidemiological studies, dental researchers formulated a hypothesis that in temperate climates 1-ppm fluoride ion in a reticulated water supply would significantly reduce dental caries with minimal dental fluorosis. In 1945 Grand Rapids became the first municipality to increase the water fluoridation level to 1ppm and commenced a ten-year experiment to test the hypothesis. Other field trials soon followed.

This was in an era of escalating birth rates, increased industrialisation and urbanisation with consequent pressure on obtaining, processing and delivering a suitable water supply. While potability and the management of water-borne enteric infections by chlorine were major issues within municipal supply, the engineers' perspective of water was wide-ranging and involved other considerations based on quality, quantity and location. In contrast, the dental profession viewed water as the ideal vehicle for the distribution of fluoride, which offered a cheap, safe, practical, effective and equitable means of curbing the dental caries epidemic.

All this early work is summarised in Dr F J McClure's historical monograph (McClure 1962).

Engineers and Fluoridation in North America

Engineers played a key role in early research into the efficacy of water fluoridation. Churchill's contribution was central to fluoride investigations and others followed. North American municipalities often had detailed records about chemical compositions of aquifers since groundwater was often used as a source for potable water. After 1931, researchers appreciated that changes in aquifer depth and/or surface supply often meant significant variation in natural ionic fluoride concentrations (McClure 1962). Engineers recorded these changes and their collective investigations contributed to a series of hypotheses linking ionic fluoride concentrations in water, enamel fluorosis and caries resistance. One early study that involved "mottled enamel" in South Dakota was co-authored by a sanitary engineer, RF Poston, and a dentist, HT Dean. Their findings relied heavily on data from the state sanitary engineer, WT Towne. Records on human and animal fluorosis gathered by dentists and veterinarians could indicate high fluoride levels enabling engineers to investigate the actual levels, and implement defluoridation technologies or seek an alternate water source. Once the optimum level of fluoride became understood, defluoridation became the source of attention in those districts where the natural potable water supply had excess fluoride (Maier 1953). One method engineers used was to dilute naturally over-fluoridated water with lower fluoridated water to produce optimal fluoride levels (Murden 1953).

Scientific collaboration between dentists and engineers became more important when addition of fluoride was implemented. Engineers supplied ionic fluoride within tight concentration parameters. As the aetiology of dental caries is multifactorial, dental epidemiology is vulnerable to many confounding factors. Inaccurate or fluctuating levels of fluoride would not only ruin an investigation but also threaten the development of water fluoridation as a public health measure. Both engineers and dentists understood epidemiology and had experience in public health. In addition, the American Water Works Association (AWWA) had kept its members up to date with the concept of fluoridation from as early as 1943. Political collaboration was also important. Engineers had prior experience with chemicals such as aluminium sulfate and chlorine and were familiar with the controversy that frequently accompanied their use. Engineers were also bureaucratic or industrial 'insiders', who could quietly give authoritative opinions within the political process.

From the engineer's perspective, fluoridation had characteristics that differed from chlorination. Firstly, fluoridation involved a long period before benefit appeared. Secondly, unlike chlorination, which virtually eliminated water-borne enteric infections, fluoridation was only a partial solution to a public health problem, albeit an important one. In addition, fluoridation involved an additive process with a narrow concentration range. Fluoride was odourless, tasteless and, if imbibed in excess, caused a permanent mottling effect on the developing enamel. Unlike the warning smell of surplus chlorine, excess fluoride could not be detected without analysis. Rapid and accurate water-based fluoride monitoring was essential for therapeutic dosage and effective fail-safe systems. Again engineers played pivotal roles in the evolution and

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implementation of such assay, screening and safety technologies (Harper 1951).

By 1951, approximately 13,000 public water supply systems serviced 85,000,000 people in the United States delivering approximately 15 billion gallons of water per day (57Gl/d) (Allen *et al.* 1951). When water fluoridation was approved for a municipality, engineers customised the installations based on economics, space, feeding mechanism and safety protocol (Harper 1951). Sanitary engineer FJ Maier and chemical engineer E Bellack were responsible for early research into the engineering problems and waterworks safety protocol involved in the dispensing of fluoride into the water supply (McClure 1962). The news magazine of the American Chemical Society, *Chemical and Engineering News,* also carried regular articles on fluoride related matters, including transport guidelines (Miller 1949).

The Crystallisation of an Opposition

Between 1945 and 1952, 183 United States' communities adopted water fluoridation but only twenty-four involved referenda and by 1953, fourteen communities had discontinued fluoridation (Crain *et al.* 1969, Black 1955). Between 1951 and 1954, overt opposition to water fluoridation had emerged in the United States. While the first defeat of fluoridation at a referendum occurred at Stevens Point in 1950, the resounding defeat (86,230 to 44,814) of fluoridation in Seattle in 1952 attracted extensive publicity (1952, Crain *et al.* 1969). Two congressional hearings, one on chemical additives to foods and cosmetics in 1952 and the other on a bill to prohibit fluoridation in 1954 provided widely publicised arguments for and against water fluoridation resulting in the formation of an international anti-fluoride movement (Doty *et al.* 1952; Danziger 1954). Between 1946 and 1950, water fluoridation was novel and almost universally welcomed, but by 1952 the "honeymoon" acceptance period was over and convincing communities to adopt water fluoridation usually became a political rather than health issue.

North American Water Fluoridation and the AWWA

The liaison between AWWA and dental researchers on fluoride was longstanding. Two dental researchers (HT Dean and D Ast) delivered papers on dental epidemiology, fluoridation and dental caries to the 1943 AWWA Conference. An AWWA policy accepting controlled experimental tests into water fluoridation soon followed (Wolman 1943). Between 1943 and 1949, the water works industry generally approved controlled pilot studies but recommended avoiding a more general adoption of water fluoridation until the completion of those studies (Faber 1949). In 1949 there was a significant AWWA policy change to accept wider water fluoridation under certain conditions. The policy now read (Black *et al.* 1949):

> "In communities where a strong public demand has developed and the procedure has the full approval of the local medical and dental societies, and the local and state health authorities, and others responsible for the communal health, water departments or companies may properly participate in a program of fluoridation of public water supplies."

This modification was adopted during the "honeymoon" era for fluoridation acceptance and largely preceded the emerging socio-political controversy surrounding water fluoridation. It established protocols and accelerated fluoridation. Engineers were given a clearly defined position and uniform installation procedures. Fluoridation now involved a fee that was levied on health departments rather than as *per capita* water consumption cost, recognising fluoridation as a health responsibility. Furthermore, public utilities accepted liability for negligence for too high and too low a dosage (Black *et al.* 1949). As the sole municipal provider, water utilities occupied a privileged legal position. They had dual accountabilities (Waldrep 1952). The first was a proprietary responsibility to supply water profitably. The second was a governmental role to benefit the public. By 1952, the AWWA investigated the legal issues involved in water fluoridation and advised its membership that although the fluoridation process was legal, there were obscurities involving public indemnity (Murdoch 1952, Waldrep 1952).

The 1949 policy also meant that AWWA accepted the validity of the dental evidence, whilst the longitudinal experiments were still underway. Moreover, the active participation by the engineering profession implied that it was comfortable with artificial fluoride protocols and with the safety aspects of the narrow concentration limits. Other feeder compounds that offered economic advantages could now be investigated more thoroughly. While comparatively few engineers became overt fluoride advocates, the *Journal of the American Water Works Association* kept its membership well informed. Between 1948 and 1953 it published at least twenty-five fluoride related articles. These included articles by high profile researchers, the National Research Council, attorneys and even "Questions and Answers" to public questions. There was also discussion on alleged problems involving ice manufacture, fermentation procedures and wet-milled corn. In addition, there was obvious collaboration between dentists and engineers in official AWWA statements (Black *et al.* 1949).

Background to Australian Water Fluoridation

Australian dentists were able to follow North American developments on fluoridation in their local dental publications. Nonetheless, Australian scientific bodies appreciated that water fluoride implementation could not be merely translocated across the Pacific if for no other reason than the higher water ingestion in tropical climates such as North Queensland. The Australian background to water fluoridation was vastly different from North America's. In Australia the only communities with naturally occurring fluoride in drinking water with levels approaching or exceeding 1ppm were in rural and remote areas. The populations involved were too small to attract the attention of epidemiologists. Moreover, the Commonwealth Department of Health did not have the authority, finances or cohesive national approach of the United States Department of Health, Education and Welfare. The United States Public Health Service, which was responsible for much of the multidisciplinary organisation within the North American field studies, had no Australian equivalent. Furthermore, Australian dentistry did not have the same research culture as North America. Epidemiological investigations into the incidence of dental caries and fluoride ingestion were lacking in Australia of the 1940's. The National Health and Medical Research Council (NHMRC) was Australian's peak advisory body on scientific developments. In the immediate post-war era, the dental activities of the NHMRC were limited and, in the case of fluoridation, restricted by its charter. The NHMRC funded research but did not offer legislative or fiscal recommendations. Resources were limited and dental research had to compete for grants with research into diseases such as poliomyelitis and tuberculosis. Dental research was the function mainly of universities where there were also fiscal restraints. Furthermore, after 1953 the Dean of the University of Melbourne Dental School, Professor (later Sir) A Amies, emerged as a high profile anti-fluoridationist. As a consequence, Mr N Martin (later Professor and Dean of the University of Sydney Dental School), and

Sydney's embryonic Institute of Dental Research, provided the early research into dental caries and fluoride.

Formal Australian acceptance of fluoridation did not occur until December 1953, when the NHMRC prepared its scientific protocol. This delay placed Australian water fluoridation firmly into the political arena of the emerging anti-fluoridation movement without the "honeymoon" period enjoyed by North America. During this period, the dental profession was fragmented across state boundaries. Although the federal representative body, the Australian Dental Association (ADA) existed, it did not have the established structure and profile of the American Dental Association. This impeded the advocacy role of the ADA. Furthermore, although politicians tacitly acknowledged caries as a national problem, fluoridation could not be implemented on a national basis because health was not a mainstream federal responsibility and even at the state level, complications arose from the different legislative control over water supplies. The collective consequence was a widespread lack of co-ordination within fluoride advocacy, which further delayed fluoride implementation (Editorial 1951).

Engineers and Fluoridation in Australia

The Australian literature on early fluoridation documents significant input from four engineers - Mr F Grey (Tasmania), Mr H J N Hodgson (South Australia), Mr M A Simmonds (Queensland) and Dr M J Flynn (New South Wales). Grey was the Beaconsfield Municipal Council's Waterworks Supervisor, whose enthusiasm and support was responsible for the 1953 Australian fluoridation debut at Beaconsfield. Grey, a graduate from the Melbourne Technical Institute, was an industrial chemist, metallurgist and mining engineer. He solved persistent turbidity problems within the municipal water supply, which endeared him locally because people now enjoyed "a real cup of tea" (Hooper 2000). Grey turned his attention to water fluoridation, which had ministerial, departmental and local authority support because of a perennial shortage of dentists in Tasmania. Grey knew about the benefits of fluoride in the United States (Australian Dental Association-Federal Branch 2003). Beaconsfield was the first town to adopt water fluoridation in Australia and it was an independent municipal authority decision. Tasmania generally looked to Victoria for its dental science information but on water fluoridation Amies' views were an emerging problem. This evidence and local archives suggest that Grey's practical information came from AWWA, which by 1951 had published detailed instructions about fluoridation equipment (Harper 1951). Grey's fluoride interest was enhanced by his concerns about his daughter's teeth and he received minimal, if any, dental input. Unlike the North American pilot studies, Beaconsfield was not established as a controlled experiment but became important in investigations of the dental effects of fluoridation.

The first authoritative government report on Australian water fluoridation was published in South Australia (Hodgson 1954). Its author was a water and sewerage treatment engineer, who was attracted to the concept of water fluoridation after a visit to North America, the United Kingdom and Europe. Both North American engineers and the 1949 AWWA policy on responding to public demand for fluoridation influenced Hodgson. He recommended that "serious thought" be given to a pilot for South Australian fluoridation. After a ten-year dormancy period, Hodgson enthusiastically presented his report before the South Australian Select Committee on Fluoridation (1964), which laid the foundations for a decision "by decree" for the water fluoridation of Adelaide in 1968 (The Select Committee of the House of Assembly 1964). Hodgson convinced the Committee that "there are no engineering or mechanical problems in the fluoridation of water supplies" and his testimony was important in refuting anti-fluoride statements by Professor Sir Stanton Hicks from the Department of Physiology and Pharmacology at the University of Adelaide.

Simmonds graduated in 1929 from The University of Queensland as a chemical engineer. He later became Engineer-in-Charge at the Brisbane City Council's Mt Crosby Water Plant. In 1949, he joined the Queensland Department of Local Government, as Executive Engineer (Chemical). In 1952, Simmonds advocated the fluoridation of Townsville's water supply, but his proposal was premature in that there were no NHMRC guidelines in place. Queensland health bureaucrats and the Australian Dental Association (Queensland Branch) rebuffed Simmonds' proposal (Simmonds 1952). Regrettably, many of his early archives were destroyed in the 1974 Brisbane flood. However, in a manuscript published in the 1952 *Queensland Dental Journal* he displayed a detailed knowledge of fluoridation including contemporaneous material on dosage variation related to age and climate. This paper exposed an enthusiasm, persistence and ability to network within government departments. Simmonds was clearly disappointed by Queensland hesitance to adopt his recommendations. It is arguable that Simmonds was the first water fluoridaton advocate in Queensland (Akers *et al.* 2004).

Simmonds' professional files confirmed his commitment to water fluoridation. While he relied on information from the AWWA, he also had contact with the American and Australian Dental Associations, the NHMRC and Queensland's leading health officials. In 1955, Simmonds wrote an unpublished paper, *Fluoridation of Public Water Supplies: A Water Engineer's Point of View,* which, at that time, was the most detailed report on fluoridation in Queensland (Simmonds 1955). It concluded, "As engineers we merely await an instruction from those in authority." Simmonds was related to Mr G Simmonds, a dentist and emerging fluoride advocate. Style and references suggest that they collaborated with publications (Simmonds 1951, Simmonds 1952). M Simmonds was responsible for some of the planning and infrastructure of a Queensland fluoridation plant at Dalby. His intimate knowledge of fluoride levels within the state's artesian system precipitated an interest in defluoridation technologies, especially in the northwest.

The last 'engineer' in this discussion of early fluoride engineers is Dr M J Flynn, who was appointed Chief Medical Officer of the Metropolitan Water, Sewerage and Drainage Board (Sydney) in 1957. Flynn, whose *curriculum vitae* included medical, engineering and public health qualifications, became a major influence within Australian fluoride politics. He authored a 1964 report on fluoridation for the New South Wales government and co-published with Martin, whom he regarded as one of two men who were leaders in Australian fluoridation (Flynn *et al.* 1963, Flynn *et al.* 1964). Flynn named his colleague Hodgson as the second leader, and at the 1964 South Australian Select Committee hearing, endorsed Hodgson's 1954 view that South Australia should initiate fluoridation (The Select Committee of the House of Assembly 1964). While this Flynn-Hodgson synergism was influential in South Australia, it was exceeded on the Australian stage by the Flynn-Martin liaison. This association amalgamated the multidisciplinary interests within fluoride advocacy, namely dental, medical, communal health and engineering expertise. Both Flynn and Martin became World Health Organisation consultants; New

South Wales Fluoridation Advisory Committee Members and Flynn later became President of the Australian Water and Wastewater Association. Although Flynn traversed Australia as an expert witness endorsing fluoridation he met his biggest test in Sydney. In mid-1963, the Metropolitan Water, Sewerage and Drainage Board rejected his advice and voted 4-2 against fluoridation. The New South Wales' Minister for Health, WF Sheahan, quickly attacked the Board's decision. Sheahan endorsed Flynn and his stand on fluoridation, which precipitated state government action that was responsible for much of the fluoridation of water supplies within New South Wales. Flynn's unequivocal commitment was demonstrated in the Victorian Supreme Court where a 1964 legal challenge to municipal fluoridation was underway. In an attempt to demonstrate the safety of fluoridated water at 1ppm, Flynn dissolved twenty milligrams of sodium fluoride in a glass of water (which became 50ppm fluoride) and drank it before Justice Gilliard (1964)). The testament to Flynn's profile and effectiveness is reflected not only in his achievements, but also in the attention he received from antifluoridationists.

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